Differences Between Tropical and Trade-Wind Shallow Cumuli

Research Highlight

Boundary layer cumulus clouds are routinely observed over the tropical and subtropical oceans. These clouds have a significant impact on the Earth's energy and hydrologic cycle, and hence need to be accurately represented in Earth System Models (ESMs) aimed at predicting the future climate and energy needs. The marine cumuli are usually tiny (less than 500 m in size) and often last for a short period of time (~30 mins or so). As these scales are much shorter than the grid resolution (~100 km) of the ESMs, the effects of the marine cumuli and those of the associated processes need to be parameterized in the ESMs using some measure of model resolved variables. A cumulus parameterization needs to represent the cumuli in the tropical and trade wind region using the same physical basis, although the model resolved variables differ significantly between them. The cumulus lifetime and lifecycle is not only affected by the large-scale forcing such as surface fluxes and winds, but also by small-scale processes such as radiative cooling, microphysics, and precipitation.

In this study, we used observations collected during the deployment of the Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF) at the island of Graciosa in the Azores, and observations made at the ARM observing facility on Manus Island to contrast the dynamic, thermodynamic, and radiative structure of tropical and trade-wind cumulus topped marine boundary layers.

About 200 hours of data from Manus containing 685 cumulus cloud elements and 166 hours of data from the Azores containing 747 cloud elements were analyzed in the study. Data collected by multiple instruments including the vertical pointing Doppler cloud radar, ceilometer, microwave radiometer, and radiosondes along with reanalysis models were used to characterize the cloud and environmental structure at both locations. The mean Doppler velocity observations from the cloud radar were used as a surrogate for vertical air motion during nonprecipitating conditions. The boundary layer radiative fluxes and heating rates were retrieved using a one dimensional radiative transfer model at high spatial and temporal resolution.

Our observations show the tropical cumuli to be on average thicker with higher cloud base height than the trade-wind cumuli. However, the trade-wind cumuli were significantly wider (greater cloud chord length) than the tropical cumuli. This resulted in the trade-wind cumuli having higher hourly cloud fraction and liquid water path values than the tropical cumuli. The surface fluxes and radiative cooling near boundary layer top were larger at Manus than at the Azores. This resulted in the cumuli over Manus having greater in-cloud updraft velocities than cumuli over the Azores. The mean in-cloud and near cloud base radar reflectivity of tropical cumuli was greater than the trade-wind cumuli.

Our results collectively suggest the tropical and trade-wind cumulus topped marine boundary layers differ significantly in their dynamic, thermodynamic, and radiative structures. Although the processes occurring in these two boundary layers are similar, the results suggest that the relative impact of these processes on the cumuli may differ significantly between the two regions.

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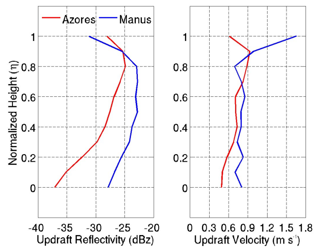

Cloud depth normalized profiles of averaged radar reflectivity within updrafts (left) and updraft velocity (right) for clouds over Manus (blue) and Azores (red). The cumuli over Manus had higher radar reflectivity and updraft velocity at the cloud base than those over the Azores.

Reference(s)

Ghate VP, MA Miller, and P Zhu. 2015. "Differences between Nonprecipitating Tropical and Trade Wind Marine Shallow Cumuli." Monthly Weather Review, , . ACCEPTED.

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Cloud Life Cycle